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Declaration

I, Mariko Uchida, a translator of Fukuyama Sangyo Honyaku Center, Ltd., of 16-3, 2-chome, Nogami-cho, Fukuyama, Japan, do solemnly and sincerely declare that I understand well both the Japanese and English languages and that the attached document in English is a full and faithful translation, of the copy of Japanese Unexamined Patent No. Hei-8-299447 laid open on November 19, 1996.

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ACTIVE BENDING MECHANISM OF TUBULAR OBJECT

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SPECIFICATION

[TITLE OF THE INVENTION]

Active bending mechanism of tubular object

[ABSTRACT]

[Object] To provide a tubular object whose manufacturing is easy while being small in diameter and having minute components and having a structure where the same can freely bend by itself in accordance with an external operation, so that the same can proceed inside a winding insertion route in a manner favorably following its curvature.

[Construction] An active bending mechanism of a tubular

object wherein, at the outside of a flexible tubular object 1, at least fitted are: (A) connecting units 2 fitted at a desirable number at desirable intervals in the longitudinal direction of a tubular object; (B) shape-memory members 3a, 3b, and 3c which are formed so as to make it possible to rise in temperature as a result of electricity supply and contract or expand in the longitudinal direction, and whose both end portions are connected to respective connecting portions of adjacent connecting units to couple these connecting units to each other, and (C) conducting wires 4 provided, in order to make it possible to individually supply electricity to shape-memory members, at a required number along a tubular object from an operation-side end portion of the tubular object and connected to connecting portions of desirable connecting units are fitted.

[WHAT IS CLAIMED IS;]

[Claim 1] An active bending mechanism of a tubular object wherein, at the outside of a flexible tubular object, at least the following connecting units (A), following shape-memory members (B), and following conducting wires (C) are fitted.

(A) Connecting units fitted at a desirable number at desirable intervals in the longitudinal direction of a tubular object, wherein

to the individual connecting units, a through hole to be penetrated by said tubular object is provided; and on the external surfaces of said connecting units, connecting portions to which shape-memory members are individually connected, connecting portions to which conducting wires are connected, and conductive paths for connecting these connecting portions according to desirable combinations are provided.

(B) Shape-memory members which are formed so as to make it possible to rise in temperature as a result of electricity supply and contract or expand in the longitudinal direction, and whose both end portions are connected to respective connecting portions of adjacent connecting units to couple these connecting units to each other, wherein

for coupling adjacent connecting units to each other, three shape-memory members or more are arranged on the outer circumference of a tubular object so that the tubular object between the connecting units can be freely bent in an arbitrary direction.

(C) Conducting wires provided, in order to make it possible to individually supply electricity to shape-memory members, at a required number along a tubular object from an operation-side end portion of the tubular object and connected

to connecting portions of desirable connecting units.

[Claim 2] The active bending mechanism of a tubular object as set forth in Claim 1, wherein

the connecting units employ a laminated structure as an essential feature where glass layers and silicon layers are alternatively laminated.

[Claim 3] The active bending mechanism of a tubular object as set forth in Claim 1 or Claim 2, wherein

the laminated structure to be an essential feature of a connecting unit is a hexahedron formed by laminating a glass layer as a first layer, a silicon layer as a second layer, a glass layer as a third layer, and a silicon layer as a fourth layer in order, a middle layer in which a through hole is provided extends to the third layer and fourth layer, the connecting portions for the conducting wires are provided on an upper surface of the first layer, and the connecting portions for the shape-memory members are provided on both side surfaces of the third layer and a lower surface of the fourth layer. Herein, in the laminated structure, a first-layer side in the laminated direction is regarded as an upper side and a fourth-layer side is regarded as a lower side, and out of side surfaces of the laminated structure, side surfaces in a direction vertical to the longitudinal direction of the tubular

object are referred to as "side surfaces".

[Claim 4] The active bending mechanism of a tubular object as set forth in Claim 3, wherein

in the neighborhoods of both side surfaces of the second layer, vertical wiring holes penetrating this layer in the laminated direction are provided at a required number, the first layer is formed so that upper end portions of these vertical wiring holes are opened, the connecting portions for the shape-memory members to be provided on the both side surfaces of the third layer are grooves formed on the both side surfaces of the same layer, and these grooves are formed so that lower end portions of said vertical wiring holes are opened into the grooves.

[Claim 5] The active bending mechanism of a tubular object as set forth in Claim 1 or Claim 3, wherein

a number of arrangements of the shape-memory members for coupling adjacent connecting units to each other is three.

[Claim 6] The active bending mechanism of a tubular object as set forth in Claim 5, wherein

conductive paths to be provided on the external surface of a laminated structure of a connecting unit are formed of a conductive region(s) as set forth in the following (i) and/or (ii).

(i) one conductive region which makes all connecting portions for the three shape-memory members to be connected to said connecting unit while coupling said connecting unit to its one-side neighboring connecting unit conductive, and which connects the same to a desirable, one conducting wire connecting portion.

(ii) three conductive regions which connect connecting members for the three shape-memory members to be connected to said connecting unit while coupling said connecting unit to its other-side neighboring connecting unit to desirable, three conductive wire connecting portions, respectively.

[Claim 7] The active bending mechanism of a tubular object as set forth in Claim 1, wherein

the shape-memory members are provided by forming a shape-memory alloy in a coil shape, and the shape is memorized so as to contract in the longitudinal direction as a result of a rise in the temperature.

[Claim 8] The active bending mechanism of a tubular object as set forth in Claim 1, wherein

the tubular object is an object inside of which a catheter has been inserted or the tubular object itself is a catheter.

[Claim 9] The active bending mechanism of a tubular object as set forth in Claim 1, wherein

furthermore, a soft coating layer to cover the whole is provided.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Field of the Invention] The present invention relates to a catheter applicable to the medical field or all industrial fields which require observation or processing of an objective target from its outside to inside.

[0002]

[Prior Arts] In the medical field, as an instrument to be inserted into a living body to diagnose and treat an affected part with low invasion, a catheter has been employed. A catheter has various functions, such as observational functions for an endoscope, etc., operating functions for sampling, drug administration, etc., and in many cases, it is inserted deep into a winding blood vessel so as to make its front end portion reach an affected part in a living body. Accordingly, there has been a demand for an improvement such that a catheter can be more smoothly inserted while preventing a front end portion or body side-surface of the caterer from damaging a route from an entrance to the inside of a body to an objective affected part. In addition, such a demand has not only arisen in a medical-field catheter, but a similar

demand has also existed in application to observation and processing of a part where human operation is difficult and a deep position of a device.

[0003]

[Themes to be Solved by the Invention] An object of the present invention is to provide a tubular object whose manufacturing is easy while being small in diameter and having minute components and having a structure where the same can freely bend by itself in accordance with an external operation, so that the same can proceed inside a winding insertion route in a manner favorably following its curvature.

[0004]

[Means for Solving Themes and Action] An active catheter of the present invention has the following features:

(1) An active bending mechanism of a tubular object characterized in that, at the outside of a flexible tubular object, at least the following connecting units (A), following shape-memory members (B), and following conducting wires (C) are fitted.

(A) Connecting units fitted at a desirable number at desirable intervals in the longitudinal direction of a tubular object, wherein

to the individual connecting units, a through hole to be

penetrated by the tubular object is provided; and on the external surfaces of the connecting units, connecting portions to which shape-memory members are individually connected, connecting portions to which conducting wires are connected, and conductive paths for connecting these connecting portions according to desirable combinations are provided.

(B) Shape-memory members which are formed so as to make it possible to rise in temperature as a result of electricity supply and contract or expand in the longitudinal direction, and whose both end portions are connected to respective connecting portions of adjacent connecting units to couple these connecting units to each other, wherein

for coupling adjacent connecting units to each other, three shape-memory members or more are arranged on the outer circumference of a tubular object so that the tubular object between the connecting units can be freely bent in an arbitrary direction.

(C) Conducting wires provided, in order to make it possible to individually supply electricity to shape-memory members, at a required number along a tubular object from an operation-side end portion of the tubular object and connected to connecting portions of desirable connecting units.

(2) The active bending mechanism of a tubular object as set

forth in the above (1), wherein

the connecting units employ a laminated structure as an essential feature where glass layers and silicon layers are alternatively laminated.

(3) The active bending mechanism of a tubular object as set forth in the above (1) or (2), wherein

the laminated structure to be an essential feature of a connecting unit is a hexahedron formed by laminating a glass layer as a first layer, a silicon layer as a second layer, a glass layer as a third layer, and a silicon layer as a fourth layer in order, a middle layer in which a through hole is provided extends to the third layer and fourth layer, the connecting portions for the conducting wires are provided on an upper surface of the first layer, and the connecting portions for the shape-memory members are provided on both side surfaces of the third layer and a lower surface of the fourth layer. Herein, in the laminated structure, a first-layer side in the laminated direction is regarded as an upper side and a fourth-layer side is regarded as a lower side, and out of side surfaces of the laminated structure, side surfaces in a direction vertical to the longitudinal direction of the tubular object are referred to as "side surfaces".

(4) The active bending mechanism of a tubular object as set

forth in the above (3), wherein

in the neighborhoods of both side surfaces of the second layer, vertical wiring holes penetrating this layer in the laminated direction are provided at a required number, the first layer is formed so that upper end portions of these vertical wiring holes are opened, the connecting portions for the shape-memory members to be provided on the both side surfaces of the third layer are grooves formed on the both side surfaces of the same layer, and these grooves are formed so that lower end portions of the vertical wiring holes are opened into the grooves.

(5) The active bending mechanism of a tubular object as set forth in the above (1) or (3), wherein

a number of arrangements of the shape-memory members for coupling adjacent connecting units to each other is three.

(6) The active bending mechanism of a tubular object as set forth in the above (5), wherein

conductive paths to be provided on the external surface of a laminated structure of a connecting unit are formed of a conductive region(s) as set forth in the following (i) and/or (ii).

(i) one conductive region which makes all connecting portions for the three shape-memory members to be connected

to said connecting unit while coupling said connecting unit to its one-side neighboring connecting unit conductive, and which connects the same to a desirable, one conducting wire connecting portion.

(ii) three conductive regions which connect connecting members for the three shape-memory members to be connected to said connecting unit while coupling said connecting unit to its other-side neighboring connecting unit to desirable, three conductive wire connecting portions, respectively.

(7) The active bending mechanism of a tubular object as set forth in the above (1), wherein

the shape-memory members are provided by forming a shape-memory alloy in a coil shape, and the shape is memorized so as to contract in the longitudinal direction as a result of a rise in the temperature.

(8) The active bending mechanism of a tubular object as set forth in the above (1), wherein

the tubular object is an object inside of which a catheter has been inserted or the tubular object itself is a catheter.

(9) The active bending mechanism of a tubular object as set forth in the above (1), wherein

furthermore, a soft coating layer to cover the whole is provided.

[0005] An active bending mechanism of a tubular object according to the present invention is constructed such that, as a structure where a flexible tubular object can bend by itself, to a body side-surface of a section where bending of the tubular object is intended, along its longitudinal direction and at appropriate intervals in its outer circumferential direction, three shape-memory members or more are fixed at both ends of the section. In addition, the shape-memory members expand or contract in the longitudinal direction by being heated. Owing to the above-described structure, the shape-memory members act like muscles on the tubular object, and by its expansion and contraction, the tubular object within the section is bent in an arc. Accordingly, by arranging three shape-memory members or more at appropriate intervals in the outer peripheral direction of the tubular object, a bending direction can be freely composed at 360 degrees.

[0006] An expanding and contracting force of the above-described shape-memory members is transmitted to the tubular object via connecting units so as to bend the tubular object. The connecting units are fitted to both ends of the section where bending of the tubular object is intended, and to the same, both end portions of the shape-memory members are

connected. In addition, the connecting units also function as terminals to supply electricity to the individual shape-memory members. On the side surface of the tubular object, conducting wires to supply electric power for heat generation of the shape-memory members or conducting wires or the like to control the electric power distribution are laid from an operation-side end portion along the longitudinal direction of the tubular object, and the these are respectively connected to the desirable connecting units. Thereby, electricity can be freely supplied to the shape-memory members between the adjacent connecting units and temperature can be raised.

[0007] In addition, in the present invention, structure of the connecting units is crucial. A connecting unit structure employs a laminated structure where glass layers and silicon layers are alternatively laminated as a basic essential feature, and therein various groove portions and through holes are provided. By providing such a laminated structure, a micro-processing technique for silicon can be applied as it is to a connecting unit processing. Accordingly, it becomes easy to process connecting units in a minute and complicated shape and to, for example, form a wiring pattern on the surfaces thereof, and it becomes possible to form connecting units in

bulk. Moreover, it is extremely difficult to fabricate a minute and complicated structure from one member, and preferably, this is fabricated by respectively applying form processings to a plurality of members and combining the same. And, in a case where one structure is fabricated from a plurality of members as such, it is necessary to carry out adhesion of the respective members uniformly and with high strength, and for this purpose, an anodic bonding technique is favorable. And, because the anodic bonding technique is used and the micro-processing technique for silicon is used, it is desirable to provide a laminated structure of silicon and glass by employing glass which easily attains anodic bonding with silicon.

[0008]

[Preferred Embodiment] Hereinafter, the present invention will be described in greater detail by citing an embodiment. Fig. 1 is a perspective view schematically showing an example of an active bending mechanism of a tubular object according to an embodiment of the present invention, which is a view showing a part of the whole structure. As shown in the same drawing, at the outside of a flexible tubular object 1, a desirable number of connecting units 2 are fitted at desirable intervals. In the same drawing, merely one connecting unit

is illustrated. This connecting unit is coupled to a one-side neighboring (on the right in the same drawing) connecting unit by three shape-memory members 3a, 3b, and 3c. Similarly, this connecting unit is coupled to another-side neighboring (on the left in the same drawing) connecting unit by three shape-memory members 3d, 3e, and 3f. In the same drawing, by illustrating the tubular object in an appropriately short cut-away manner, the shape-memory members 3c and 3f in the background are expressly shown. In addition, a plurality of conducting wire sets 4 are provided at a required number from an operation-side end portion of the tubular object 1 along the tubular object, and in order to make it possible to individually supply electricity to all shape-memory members, these are separated in desirable connecting units as will be described later and are connected to respective connecting portions. By this mechanism, electricity can be supplied to the shape-memory members for coupling adjacent connecting units all individually, whereby it becomes possible to bend a tubular object between the adjacent connecting units in an arc form in an arbitrary direction.

[0009] The tubular object can be any object as long as it has flexibility, and can be a simple tube and a tubular device composed of a plurality of components such as a catheter. In

a case where the tubular object is a simple tube, after assembling the same as an active bending mechanism, a catheter may be inserted in the inside for use. In addition, as the tubular object, an object having a moderate elasticity causing no plastic deformation is preferable, and in particular, an object which does not deteriorate against repeated bending is more preferable. In addition, rigidity is provided as necessary. In a case where the tubular object is a simple tube, a material such as silicone rubber, Teflon, nylon, etc., can be mentioned. The sectional shape, outside dimensions, and inside dimensions of the tubular object are not limited, and a tubular object with favorable values can be selected, from application to the inside of a large-scale manufacturing equipment to application to a small blood vessel, according to the uses. Among these uses, a use where being thinner and multifunctional is demanded such as a medical catheter is rather preferable since this takes advantage of a feature of the present invention enabling micro-processing. For example, in a case where the tubular object itself is provided as a catheter, its sectional shape is generally circular, and its outside diameter is mostly on the order of 0.2mm-3.0mm.

[0010] In terms of the number of connecting units, connecting units are fitted, at a number required for a bending shape as

a whole, along the longitudinal direction of a tubular object. For example, if the tubular object is bent in an S-shape, three connecting units or more are required. A connecting unit structure employs, as schematically shown in Fig. 2, a laminated structure where glass layers and silicon layers are alternatively laminated as an essential feature. The number of laminations of the laminated structure is not limited and can be determined according to an objective shape. In the present embodiment, a hexahedron with a laminated structure of a total of four layers, which is formed by laminating a glass layer 2a as a first layer, a silicon layer 2b as a second layer, a glass layer 2c as a third layer, and a silicon layer 2d as a fourth layer in order, is provided as an essential feature, and various form processings are applied thereto. Hereinafter, for the sake of description, among the six faces of this laminated structure, a face of the first layer is referred to as an "upper surface," a face of the fourth layer is referred to as a "lower surface," two faces in the longitudinal direction of the tubular object are referred to as "front and rear end faces," and the remaining two side faces in a direction vertical to the longitudinal direction of the tubular object are simply referred to as "side surfaces."

[0011] As a material for the glass layers, glass which can be

used in anodic bonding can be employed, and of the same, glass containing Na is particularly preferable, and for example, Pyrex Glass (Corning Incorporated, trade name), SD2 (HOYA CORPORATION, trade name) etc., can be mentioned. The silicon layers, which are made of Si, may contain impurities if these are within a range where the object of the present invention can be achieved. In addition, for the silicon layers, single crystals are generally used in relation to employment of anisotropic etching, as will be described later.

[0012] In the laminated structure, in order to enable this connection unit to be fitted to a tubular object, a through hole 11 to be penetrated by a tubular object is provided in a layer expanding direction. The layer expanding direction means a direction in which layers expand, that is, a direction vertical to a laminating direction. The forming position and forming method for the through hole are not limited, however, in the present embodiment, as shown in Fig. 2, a groove 11a is formed on a lower surface of the third-layer glass layer 2c, and by this groove and a part 11b of an upper surface of the fourth-layer silicon layer 2d, a through hole 11 whose sectional shape is rectangular is formed. By such a forming method as this, no perforating processing is required, a hole can be formed by only cutting and removing processing and

bonding processing from the end faces, therefore, even with a minute hole diameter, a hole can be processed in a simple and accurate form. The hole shape of the through hole is not limited to a rectangle as in the present embodiment, and can be a shape to most satisfactorily fit in with the tubular object. As a method for fixing the tubular object to the connecting unit, an ultraviolet curing resin, an epoxy resin, etc., can be mentioned.

[0013] On the exterior surface of the above-described laminated structure, a required number of connecting portions to which end portions of the shape-memory members are individually connected are provided. In the present embodiment, three shape-memory members are used for coupling between adjacent connecting units. Accordingly, in a case where one connecting unit is coupled to connecting units adjacent at both front and rear sides, in this connecting unit, connecting portions for shape-memory members are provided for the front and rear at three positions each, at six positions in total. These connecting portions are part where connection of the end portions of shape-memory members are intended, and are not particularly necessary to be processed into a shape distinguishable from their surroundings, however, in order to connect the end portions of shape-memory members with ease and

a sufficient mechanical strength, it is preferable to form the connecting portions in a concave shape or a convex shape. In the present embodiment, as shown in Fig. 2, one groove for each of the both side surfaces of the third layer 3 and a fourth-layer lower surface, a total of three grooves 12, 13, and 14 are provided so as to extend to the front and rear end faces, and front and rear end portions of each groove are provided as connecting portions for front and rear shape-memory members.

[0014] The above-described grooves 12 and 13 are provided by cutting away top portions where the upper surface and side surface of the third layer intersect, and therefrom both-side marginal portions of a first-layer lower surface are exposed. As a shape of a section vertical to the longitudinal direction of the groove, a shape favorable to connection of shape-memory members can be employed, and a V-shape, a U-shape, a laid U-shape, etc., can be mentioned. In the present embodiment, a sectional shape of the grooves 12 and 13 is provided as a laid U-shape, and a sectional shape of the groove 14 provided on the fourth-layer lower surface is provided as a V-shape.

[0015] As the shape-memory members, shape-memory members whose temperature rises as a result of electricity supply and which can contract or expand in the longitudinal direction can be employed. Although it is not particularly limited which of

a contraction or expansion a change toward a memorized original shape as a result of a rise in temperature is set to, because of ease in a shape-memory treatment and a subsequent deformation (for attaching a shape-memory member to a desirable position, a shape-memory treatment is performed in advance and then the shape-memory member is attached after a deformation, however, since such a deformation as to contract the same while maintaining linearity is difficult as the shape-memory member is also minute, an expanding deformation is generally performed for an attachment. Namely, the shape-memory member contracts when returning to the original shape as a result of a rise in temperature), etc., a contraction is rather preferable. For the shape-memory members, exemplified are a mode wherein shape-memory members are formed of a shape-memory alloy alone and heat generation therefrom is utilized, a mode wherein a substance which generate heat as a result of an electricity supply and a shape-memory alloy are combined to share a heat generating function and a mechanical expanding and contracting function, and a mode wherein, for example, a shape-memory alloy is coated with an insulating layer and is, furthermore, Ni-plated so as to provide an Ni-layer with a heat generating function, and the shape-memory alloy, with a mechanical expanding and contracting function. For the shape-memory

alloy, as a Ti-Ni-based alloy, a Ti-Ni binary alloy, a Ti-Ni-Cu alloy, a Ti-Ni-Nb alloy, a Ti-Ni-Fe alloy, etc., can be mentioned, and as a copper-based alloy, a Cu-Zn-Al alloy, a Cu-Al-Ni alloy, etc., can be mentioned. As a shape of the shape-memory members, a shape whose change in shape as a result of a rise in temperature includes a changing amount in the longitudinal direction can be employed, and for example, a shape such as a coil shape and a wave shape can be mentioned. In the present embodiment, only the shape-memory alloy is processed in a coil shape and the shape is memorized so as to contract as a result of a rise in temperature.

[0016] As the conducting wires to individually supply electricity to the shape-memory members, conducting wires formed of electric power lines alone or the same plus signal lines to control electric power supply at a front end portion can also be employed. The material and mode of the conducting wires can ones publicly known, and for example, electric insulated wires, etc., can be mentioned. The conducting wires are provided at a required number from an operation-side end portion of a tubular object along the tubular object, and are connected to respective connecting units. The conducting wires to supply electric power are connected so that adjacent connecting units become a pair of electrodes, and are connected

to both end portions of shape-memory members. As wiring of the conducting wires, it is preferable to reduce the wiring number of conducting wires by providing a common line on either the high-potential side or low-potential side. In addition, by providing each connecting unit with a function as a multiplexed transmission terminal, by controlling electric opening/closing of the same by a common line from a hand side, and moreover, by carrying control signals thereof on the electric power lines, electricity can be independently supplied to all shape-memory members by a smaller number of conducting wires.

[0017] In order to connect the conducting wires and shape memory members in each connecting unit, any connecting structures such as, for example, providing the conducting wires up to the end portion of a desirable shape-memory member and directly soldering the same can be employed, however, as in the present embodiment, a structure of providing conductive paths on the front surface of the laminated structure and connecting conducting wires and shape-memory members via the conductive paths is an easy and highly reliable electrical connecting structure. This connecting structure will be described in the following.

[0018] First, as shown in Figs. 1 and 2, on the upper surface

of the first-layer glass layer 2a, grooves 16a, 16b, and 16c are provided in the longitudinal direction of a tubular object so that conducting wires can be stably fixed. On the other hand, the front and rear end portions of the fourth-layer groove 14 as connecting portions for shape-memory members are covered with conductors 15a and 15b, and these conductors are formed as conductive paths while extending their regions to the neighborhoods of the grooves 12 and 13. In Fig. 1, these conductive paths are shown with hatching applied. As a material for the conductive paths, a good conductor metal is preferable, and Al, Au, CU, Ag, etc., can be mentioned. In addition, as a method for forming the conductive paths, a publicly known film-forming method such as a sputtering method, a vacuum evaporation method, and plating can be employed. Furthermore, as shown in Fig. 2, in the neighborhoods of both side surfaces of the second layer 2b, vertical wiring holes 17 and 18 penetrating this layer in the laminated direction are provided at a required number per each side. Vertical wiring holes of the present embodiment are provided, as shown in Fig. 1, at three positions of 17a, 17b, and 17c per one side. Upper ends of these vertical wiring holes are opened by cutting away the neighborhoods of both side surfaces of the first layer 2a. In addition, lower ends of the vertical wiring holes are

opened into the grooves 12 and 13 of the third layer, which are connecting portions for shape-memory members. It is preferable to form, on the inner wall surface of the vertical wiring holes, a conductor layer similar to the above-described conductive paths.

[0019] By such a structure provided with conducting paths and vertical wiring holes as above, the conductive path 15a makes it easy, as shown in Fig. 1, to make all connecting portions for three shape-memory members 3d, 3e, and 3f to couple that connecting unit to a connecting unit on its left in the drawing conductive. Furthermore, it becomes easy to connect the same to a common ground wire through the vertical wiring holes, thus high reliability can be obtained without taking up wiring space. In addition, the conductive path 15b makes it easy to, out of three shape-memory members 3a, 3b, and 3c to couple that connecting unit to a connecting unit on its right in the drawing, make 3a and conducting wires 4 conductive inside a groove 12 center portion or 13 center portion. In addition, the shape-memory members 3b and 3c are, while respectively utilizing the end portions of the grooves 12 and 13 as connecting portions, connected in the grooves, and connection between these and the respective conducting wires can also be made easy with space-saving by the vertical wiring holes, thus

high reliability can be obtained. The present embodiment is constructed such that, by such wiring, one-side ends of the individual shape-memory members are connected to a common ground wire, the other-side ends are individually connected to conducting wires, and electricity is individually supplied to these shape-memory members from a hand operation side.

[0020] For mechanically or electrically connecting the shape-memory members and conducting wires to the connecting portions and conductive paths, an ultraviolet curing-type conductive resin shown as 19 in Fig. 1, soldering, wire bonding, etc., can be exemplified.

[0021] For an active bending mechanism of the present invention, it is preferable, in actual use, to provide a coating layer on the outside by use of a flexible material, and in particular, when the active bending mechanism is used in a manner inserted in a living body, it is preferable to cover the whole with a soft tube made of silicone rubber, Teflon, polyurethane, or polyvinyl chloride.

[0022] [Manufacturing experimentation] An active bending mechanism of the present invention was actually manufactured with use of a catheter as a tubular object, and ease in processing of a connecting unit during manufacturing and product performance were confirmed. Manufacturing and

assembling steps thereof will be hereinafter described in an outline.

[0023] (1) Fabrication of a connecting unit

Fig. 3 denotes views schematically showing an outline of connecting unit processing steps. (A)-(D) of the same drawing are views of conditions where a connecting unit is processed from a longitudinal direction of a tubular object to be fitted. In addition, (a)-(d) of the same drawing correspond to (A)-(D) of the same drawing, respectively, and are views of these from a side-surface direction. As an outline of the all the steps, while carrying out processing and mutual bonding for a glass substrate and a silicon substrate, multiple connecting units are formed in a matrix pattern on one large laminated body, and by separating the connecting units from each other in the last stage, a large quantity of connecting units are obtained at a time. Processing in each step as shown in Fig. 3 will be described in terms of one connecting unit in the following. Fig. 3 (A) and (a); On a lower surface of a Pyrex glass substrate 2C with a thickness of 1.2mm, a groove 11a was formed by means of a dicing saw. In a step different therefrom, to a silicon substrate 2D with a thickness of 400μm, form processings for a groove 14 and other cutaway parts were applied by anisotropic etching. This silicon substrate 2D was bonded to a lower

surface of the Pyrex glass substrate 2C by an anodic bonding technique.

Fig. 3 (B) and (b); On both side surfaces and a lower surface of the laminated body composed of the Pyrex glass substrate 2C and silicon substrate 2D, aluminum was vapor-deposited to have a thickness of 1.5μm by a sputtering method, whereby a layer 15 to be a conductive path was formed. In the same drawing, this conductive path 15 is shown with hatching applied. Furthermore, by means of a dicing saw, grooves 12 and 13 were formed in the longitudinal direction on upper portions of both side surfaces of the Pyrex glass substrate 2C, and from the upper surface, grooves m and n to divide the conductive path were formed.

Fig. 3 (C) and (c); To a silicon substrate 2B of a thickness of 200μm, vertical wiring holes 17a-c (which were also provided on a 18a-side, at positions corresponding to 17a) were formed by anisotropic etching, and in these holes, aluminum was vapor-deposited. This silicon substrate 2B was bonded to an upper surface of the glass substrate 2C. Furthermore, in a different step, grooves 16a-c to attach conducting wires to an upper surface of a glass substrate 2A of a thickness of 200μm were formed, and this substrate 2A was bonded to an upper surface of the silicon substrate 2B by an anodic bonding

technique.

Fig. 3 (D) and (d); The layer 15 made of aluminum vapor-deposited on the both side surfaces and lower surface of the deposited position composed of the glass substrate 2C and silicon substrate 2D was completely separated into a conductive path 15a and a conductive path 15b. By the above processing, a wafer-state object where, on a four-layered laminated body composed of 2A-2D, multiple connecting units in a completed condition were formed in a matrix pattern was obtained. This was separated by means of a dicing saw to obtain individual connecting units S.

[0024] (2) Fabrication of a catheter having an active bending mechanism

In the present experiment, five connecting units were to be fitted onto a catheter.

[1] As shown in Fig. 1, five connecting units 2 were fitted to the outside of a catheter 1, and these were fixed by an ultraviolet curing resin. The connecting units were arranged to be equally spaced with a center-to-center pitch of 3.5mm.

[2] Three shape-memory members, which have a length covering all these five connecting units arranged on the catheter and had been expanded by an appointed amount in advance, were employed and fitted so that these were contained in the

respective grooves 12, 13, and 14, and these were mechanically and electrically connected at desirable connecting portions by use of an ultraviolet curing-type conductive resin.

[3] By means of a YAG laser, the above-described shape-memory members were separated so as to become individual shape-memory members for a connection only between desirable connecting portions of adjacent connecting units, whereby making it possible to independently bend the caterer between the connecting units.

[4] Conducting wires were laid along the catheter and attached to conductive wire-attaching grooves of the respective connecting units, and desirable conducting wires were connected to end portions of the shape-memory members and conductive paths through vertical wiring holes of the connecting units.

[5] The whole was covered with a tube made of silicone rubber, whereby a catheter capable of active bending with an outside diameter of ϕ2.8mm was obtained.

[0025] Through the above-described manufacturing experimentation, it was confirmed that a micro-processing technique for silicon in integrated circuit manufacturing, etc., could be applied as it is to connecting unit processing. In addition, when an active bending mechanism of the obtained

catheter was operated, it was confirmed that, despite being small in diameter, the catheter could be freely bent in an arbitrary direction.

[0026]

[Effect of the invention] As in the above, an active bending mechanism of a tubular object according to the present invention can freely bend by itself in accordance with an external operation despite being small in diameter and, therefore, can proceed inside a winding insertion route in a manner favorably following its curvature. Accordingly, the present invention can be applied not only to a catheter applied to the inside of a living body but also to an observation and processing operation of the inside of a nuclear reactor and engine piping, and it can also be a tool effective in maintaining a complicated system without disassembling.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1] A perspective view schematically showing an example of an active bending mechanism of a tubular object according to an embodiment of the present invention.

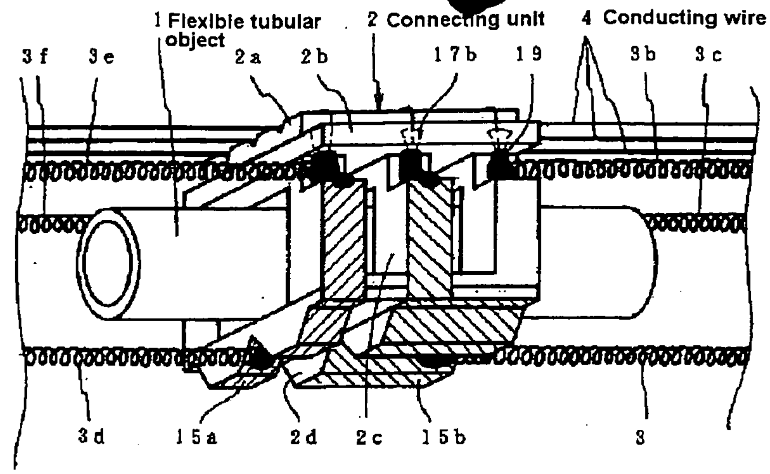
[Fig. 2] A view schematically showing a connecting unit structure.

[Fig. 3] Views schematically showing an outline of connecting unit processing steps.

[Description of Symbols]

1	Flexible tubular object
2	Connecting unit
3a-3f	Shape-memory members
4	Conducting wire

Fig.1



3a-3f: Shape-memory members

Fig.2

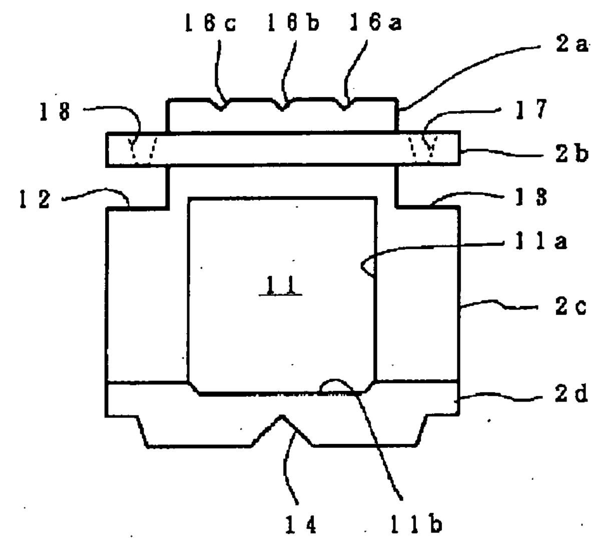


Fig.3